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PDS CSI Program Proposal
The Topography of Comet Tempel 1 as Determined From Images of the Deep Impact Mission

Abstract

This project involves determining the topography of comet Tempel 1, which was impacted during the Deep Impact mission, to provide more detail regarding the comet's surface structure for further analysis of the evolutionary processes cometary bodies undergo. We estimate the topography using data returned from the Deep Impact spacecraft, including Impactor Targeting Sensor (ITS) and Medium Resolution Instrument (MRI) images. Stereo pair images are used as the main method of identifying the relief of the topographical features. There are two sources from which the elevation is derived. The first is the parallax resulting from the different trajectories of the ITS and MRI data; the second is the parallax attributed to the time difference between MRI images. The best resolution, limited by the combination of MRI and ITS data, is about 8 meters per pixel, which limits the range of elevations we can determine. As determining elevation relies on the position of the sun with respect to the comet, the study of the comet's topography also yields some understanding of the material of the comet, as it is necessary to sort those features with natural brightness variations due to composition from those casting shadows. Because data taken during the Deep Impact mission only distinguishably cover a portion of the comet's surface, not all surface features can be analyzed. In this work we determine, map, and then analyze those areas that have sufficient stereo coverage. The determination of the comet's morphology will lead to a better understanding of the stability of its varying structures and thus perhaps the material of which it is composed. This work is funded by NASA's Planetary Data System (PDS) College Student Investigator (CSI) program.

Introduction

Comets, to this day, remain elusive bodies within our solar system. Though scientists have speculated about their evolution and composition, there has been little conclusive data to definitively suggest or support any particular theories. More recently, however, scientists have begun to examine these issues more closely, resulting in several missions aimed at collecting data on various comets orbiting within our solar system. Deep Impact, which sent a spacecraft to impact Comet Tempel 1 in July of 2005, was one such mission.

Deep Impact was proposed to explore the structure and differentiation of cometary bodies as well as the processes by which they evolve throughout time. By impacting the comet, researchers simulated an actual process that commonly occurs within space. The material released and the resulting structure of the crater formed would then supply scientists with the data necessary to make deductions about the comet's interior. To obtain this information, the mission collected data in the form of images taken by two spacecraft, the impactor and the flyby spacecraft. These two spacecraft, initially together, separated approximately 24 hours before impact and continued to take images until that time. In the case of the flyby, images continued to be taken for several minutes after impact. Upon separation, the impactor continued on its initial course, directed towards the comet. The flyby spacecraft, however, diverted by a given angle to avoid collision (A'Hearn, et al., 2005, Space Sci. Rev. 10). A wealth of information has already been extracted from the results of this mission, including particulars regarding its overall shape and mass, but there is still a great deal of analysis to be done.

Comet Tempel 1 is not the only comet to be closely examined and analyzed to obtain new information about its structure. Others include comet Borrelly, examined during mission Deep Space 1, and comet Wild 2, examined during the Stardust mission. Each of these comets' structures were mapped and analyzed as part of their respective missions' goals. The distinguished features mapped in the topography, including overall shape, axes, and cratered regions vary greatly between the two comets. The general characteristics of Tempel 1 that have already been distinguished vary greatly from those of the other two comets despite the expectation by many researchers that each would bear some similar features (A'Hearn, 2005, Science 264). Comparing Wild 2 and Borrelly, researchers have already seen that Wild 2 is not only more spherical, but also has greater variations in elevation than does Borrelly (A'Hearn, et al., 2005, Space Sci. Rev. 7). Studies of comet Tempel 1's features add to this comparison of the varying small bodies within the solar system. Further examination of the comet's topographical features will allow for better approximations of what changes comets undergo in orbit, how these changes differ from one comet to the next, and why they differ.

Research Question

The main goal of this project is to create a topographic map that will detail the surface features of Comet Tempel 1, the comet impacted during the Deep Impact mission. A topographic map will allow us to more closely examine the comet's surface and thus have a better understanding of the stability of the individual features present. From this, researchers can deduce more about the evolution of the comet throughout time and formulate more ideas as to how and what forces have caused the shaping of comet Tempel 1's current features. The data will also aid any future follow-up missions to comet Tempel 1 by allowing for a comparison of the same comet's morphological features at two different stages. A topographical map will also be useful for making comparisons between comet Tempel 1's features and other cometary structures, such as those analyzed during the Stardust and Deep Space 1 missions.

Method

To create a topographic map of Comet Tempel 1, it will be necessary to examine stereo pair images taken during the Deep Impact mission. Thus, the first task of this project will be to find potential stereo pair images, and then determine which images will be most effective for analysis of the comet's topography. Stereo pair images are two images of the same surface features taken from different perspectives. By comparing the two images, one can calculate the approximate relief of the features being analyzed. Of the images that will be used to analyze the topography of the comet, some will be Impactor Targeting Sensor, or ITS, images taken from the impactor spacecraft of the Deep Impact mission. Other images will be Medium Resolution Images, or MRI, taken from the flyby spacecraft of the Deep Impact mission. These two sources of images will be compatible for finding stereo pair images as the two spacecraft responsible for obtaining the data diverged from the same path by a given angle, allowing for one form of parallax viewing of the comet. Not only will ITS images be compared to MRI images, but also MRI can be compared to other MRI due to the course it traveled away from the comet. The time difference between MRI images allows for a second form of parallax viewing that will contribute stereo pair data.

The data will span from the time of separation of the spacecraft until shortly after impact, when the flyby craft went into shield mode, allowing it to remain protected from small debris ejected after impact. It is likely that the best data for this task will be found amongst the images taken at closest approach to the comet. Stereo pair images used to determine the relief of the comet's surface will depend on many factors. Most importantly, selection will depend upon resolution and quality of the comet's surface. The best resolution limiting the elevations that can be determined is approximately 8 meters per pixel. Selection also depends upon other factors such as the angular separation of the spacecraft at the moment the images were taken. It is expected that certain angles will allow for better definition of features.

Once a list of all valid stereo pair images has been compiled, the next step is to begin analysis of the comet's topographic features. As the extent to which the comet was surveyed is limited by the trajectories of the spacecraft and their respective positions to the comet, only a portion of the surface will successfully be distinguished. In particular, the region of impact will likely be more difficult to distinguish as later MRI images are slightly obscured in that area. There will also be a limit to the amount of visible detail as well as a limit to the approximation of the elevation of the features.

Timeline

July 2007 – Completion of compiled list of potential stereo pair images
August 2007 – Submit final proposal to PDS Management Council
August 2007 – Edit images in preparation for determining topography
September 2007 – Calculate first relief estimates of topographic features
October 2007 – DPS Poster
February 2008 – Plot topographic relief of comet Tempel 1
April 2008 – Analysis of topographic results and implications
May 2008 – Final Report

Bibliography

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